GAMMA IN-SITU MEASUREMENTS TO ESTIMATE THE EXPOSURE OF BRAZILIAN POPULATION TO NATURAL RADIOACTIVITY

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INTRODUCTION

- The natural radiation is the main source of exposure for the average of the world population.

- The majority of the publications historically found in the literature refer to areas of high natural radioactivity.

- Recently began to appear more general publications, including assessments of external dose rates of large areas, as well surveys of natural radionuclides in soil and food and water.

- The determination of the Dose Rate (or Absorbed Dose or *kerma* or Dose Equivalent) due to exposure to radioactivity in the environment, whether natural or not, is *sine qua non* condition for all and any radiological monitoring program.

- However, it is necessary to identify which one is likely to and what quantities are calculated from these measurements.

- **H*(10)** - Ambient Dose Equivalent at 10 mm depth (operational quantity for area monitoring for radiation protection of external radiation ,defined by ICRU International Commission on Radiation Units and Measurement (ICRU) , it is becoming now the quantity widely accepted.

INTRODUCTION II

- The sources of radiation which contribute to this rate are of natural origin (cosmic radiation, radionuclides of U and Th series, Radon and Toron and ^{40}K) and also artificial (nuclear explosions, Chernobyl and Fukushima accidents, radioactive sources used on Industry and medicine);

- The two most widely used methods for the determination of radionuclide ground deposition levels are in situ gamma-ray spectrometry and germanium and soil sampling.

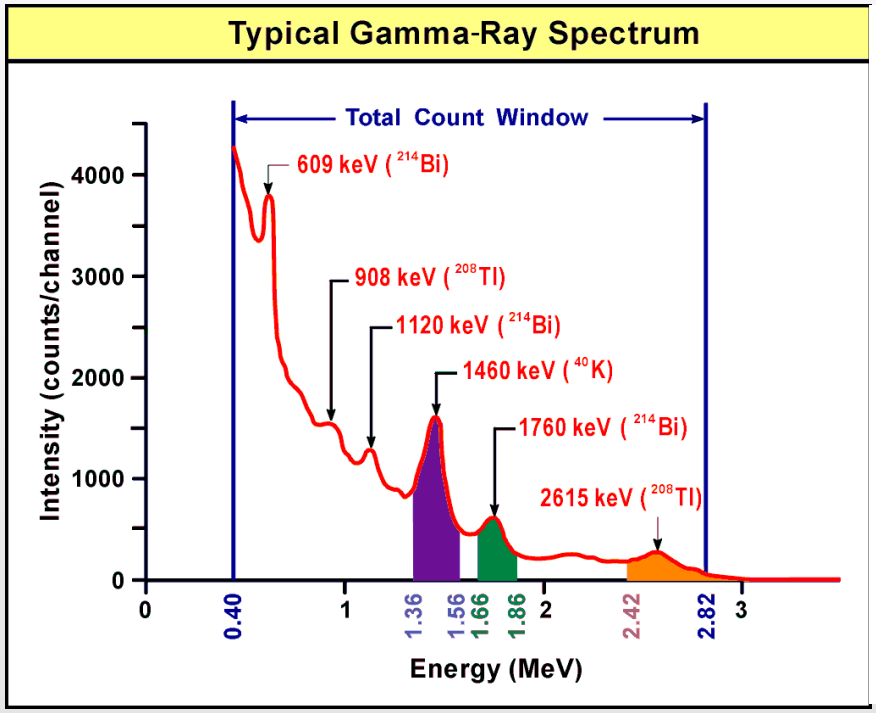
- The most used detectors are NaI(Tl) and HPGe.

- To characterize and calibrate these detectors we need reference radiation fields and the methods to calibrate the instruments.

- Environmental radiation is too complex to be artificially generated. The reference radiation is therefore given by the environmental radiation field itself. (Ambrosi, Peter, Metrologia **46 (2009) S99–S111)**

- Calibration of detectors with 137-Cs (662 keV) or 60-Co (1.17 and 1.33 MeV). Some NaI(Tl) detector can work in the range of 30keV to 1.5 or from 50 keV-3 MeV

Figure 1: Typical Gamma-ray spectrum and energy windows



Typical gamma-ray spectrometry energy windows

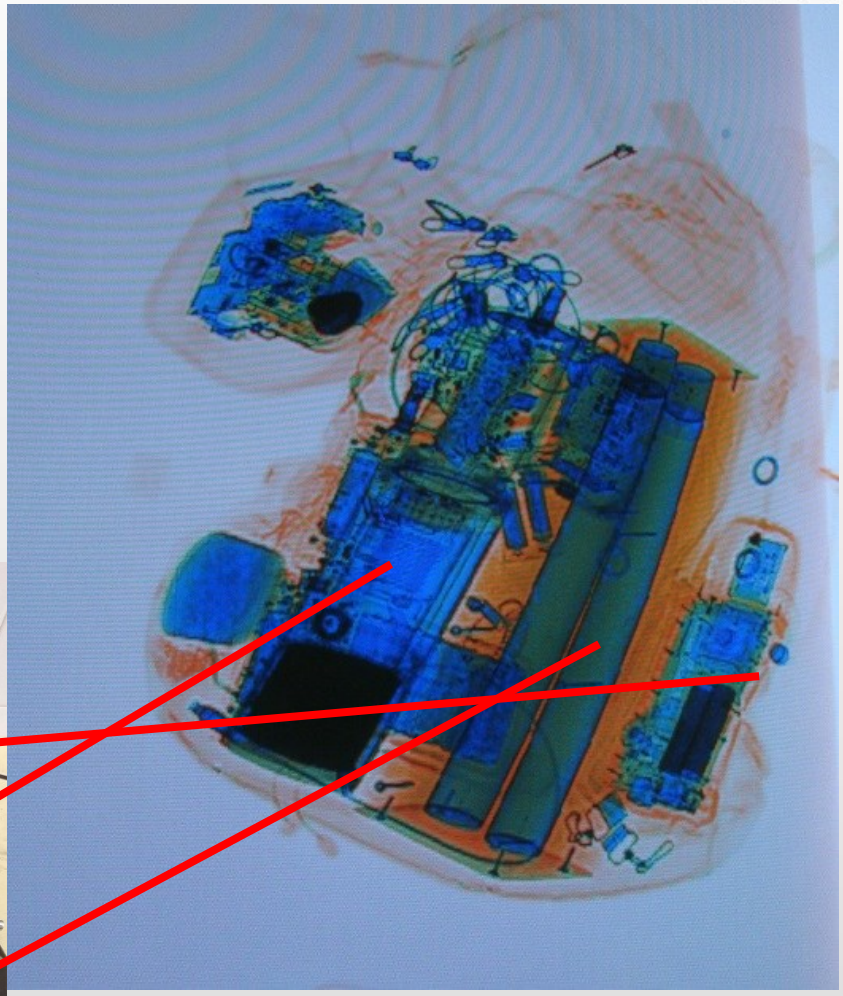
Name	Element	Peak (keV)	Energy Range (keV)
K	K40	1460	1360 - 1560
U	Bi214	1760	1660 - 1860
Th	Tl208	2615	2410 - 2810
Total Count			410 - 2810

INSTRUMENTATION I – “BACKPACK”

Figure 2 : AT6101C

(SPECTRAL RADIATION SCANNER) also known as “backpack”. Gamma and neutron radiation detectors for outdoors and indoors measurements.

512 multichannel MCA and Integrated GPS receiver. (From ATOMTEX – Belarus)



INSTRUMENTATION II

Figure 3: Spectral Radiological Airborne Computer System (SPARCS) multichannel Gamma-Ray Spectrometer with a 2×4×16 inch NaI(Tl) crystal (2 units), and one unit of data acquisition and control (ATU telemetry). (FROM DOE – United States)

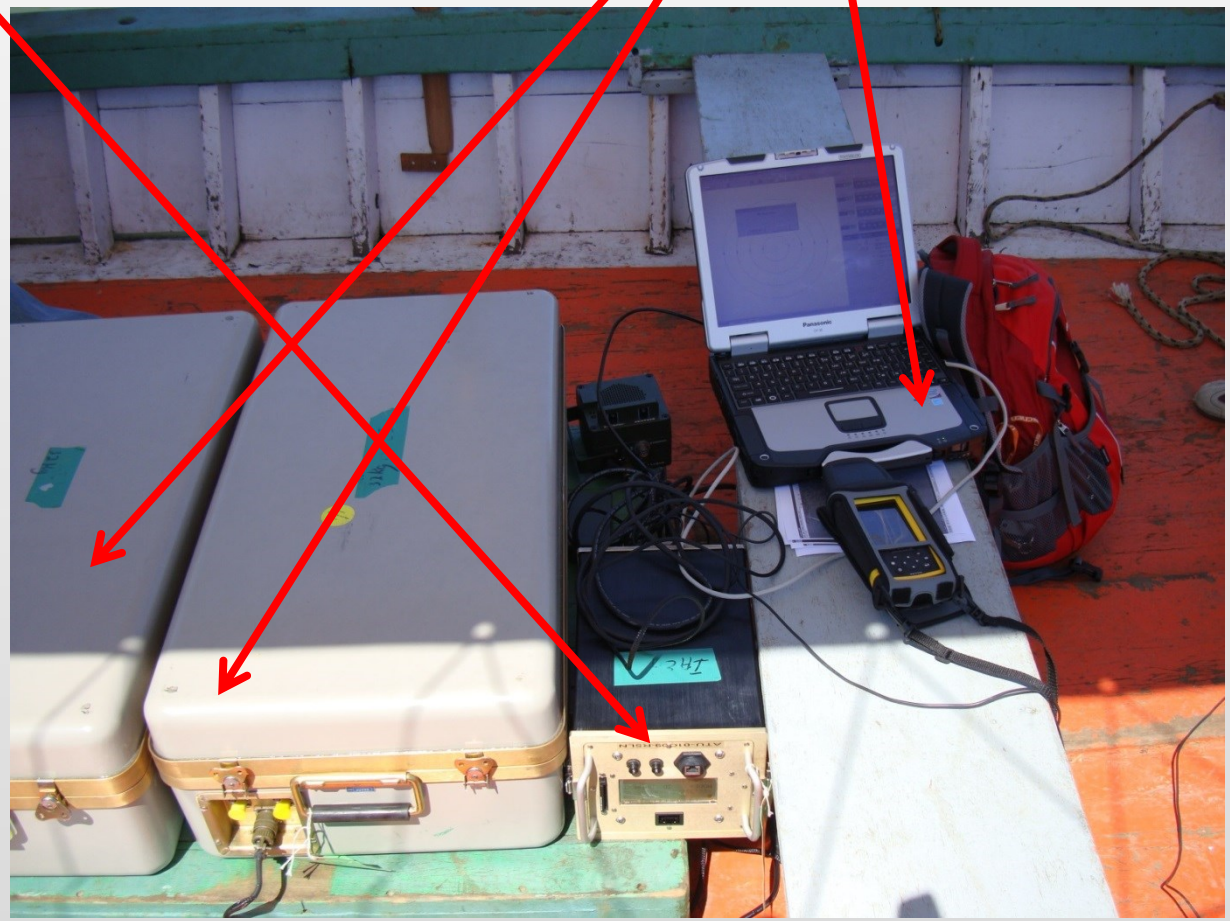


Figure 4: Pod's of known radioactive material to help the calibration of NaI/HPGe detectors. 8 planar sources with Diameter = 3 meters , and 50 cm high.

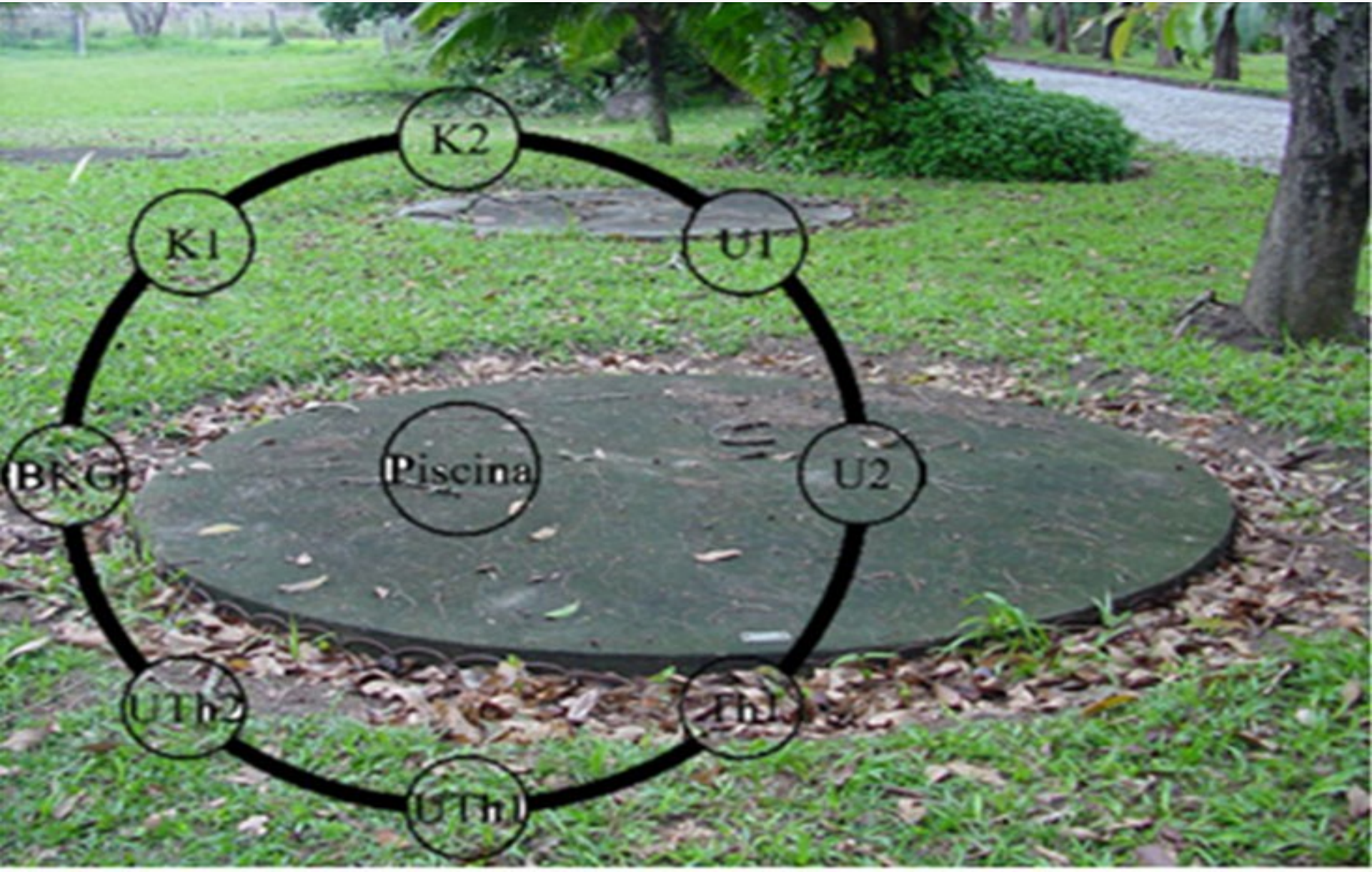


Figure 5: Details of Pod's

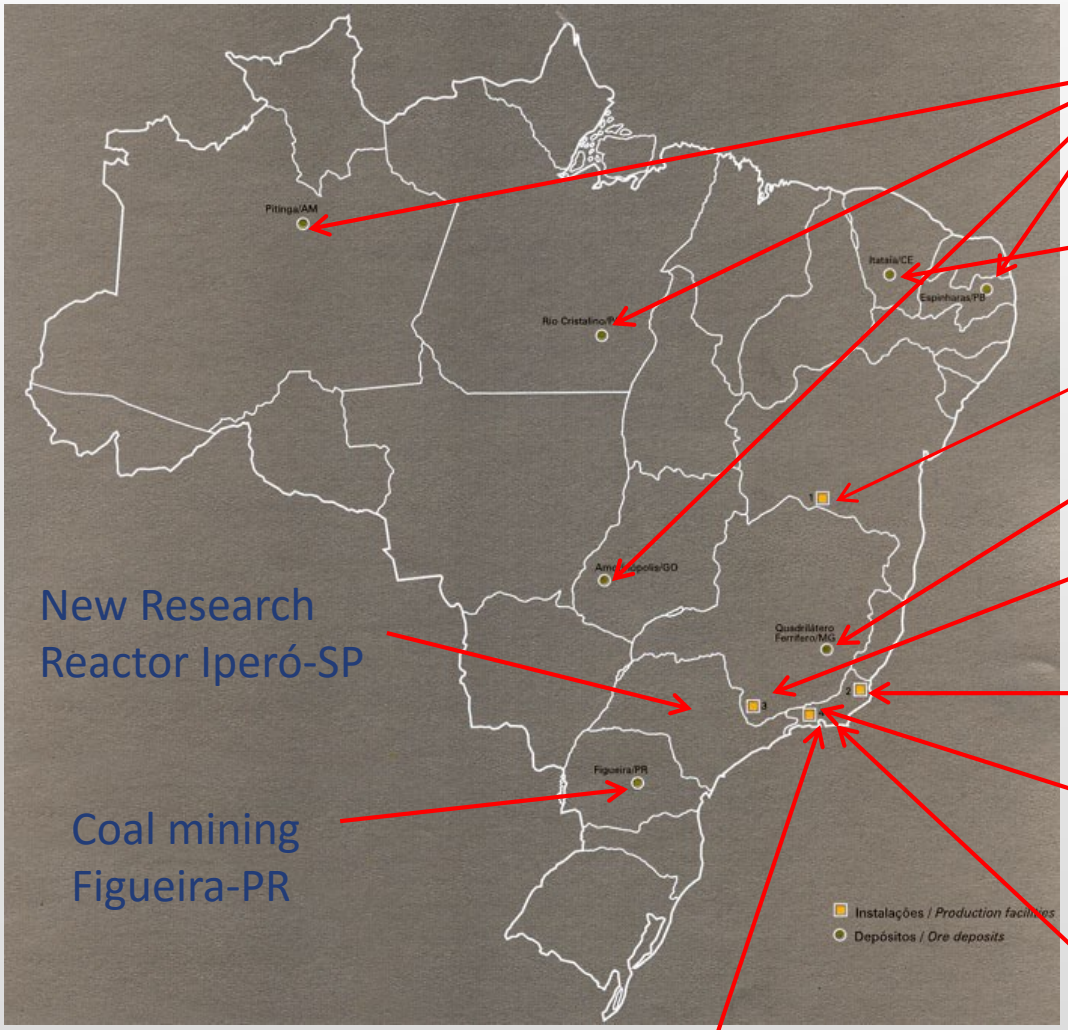
Figure 6: Proceedings to estimate the contribution of Cosmic radiation

Figure 7: Testing Sparcs system direct on the planar source

Figure 8: Testing sparcs system at 10 cm high over the planar source

Figure 9: Testing Atas Scanner AT6101c system at 10 cm high over the source

Figure 10: Brazilian Territory with some points of interest



Anomalities

Phosphate Ore

New Uranium Mine Caetité-BA

Iron mining

Former Uranium Mine Poços de Caldas-MG

New Research Reactor Iperó-SP

Monazite Sands

Coal mining Figueira-PR

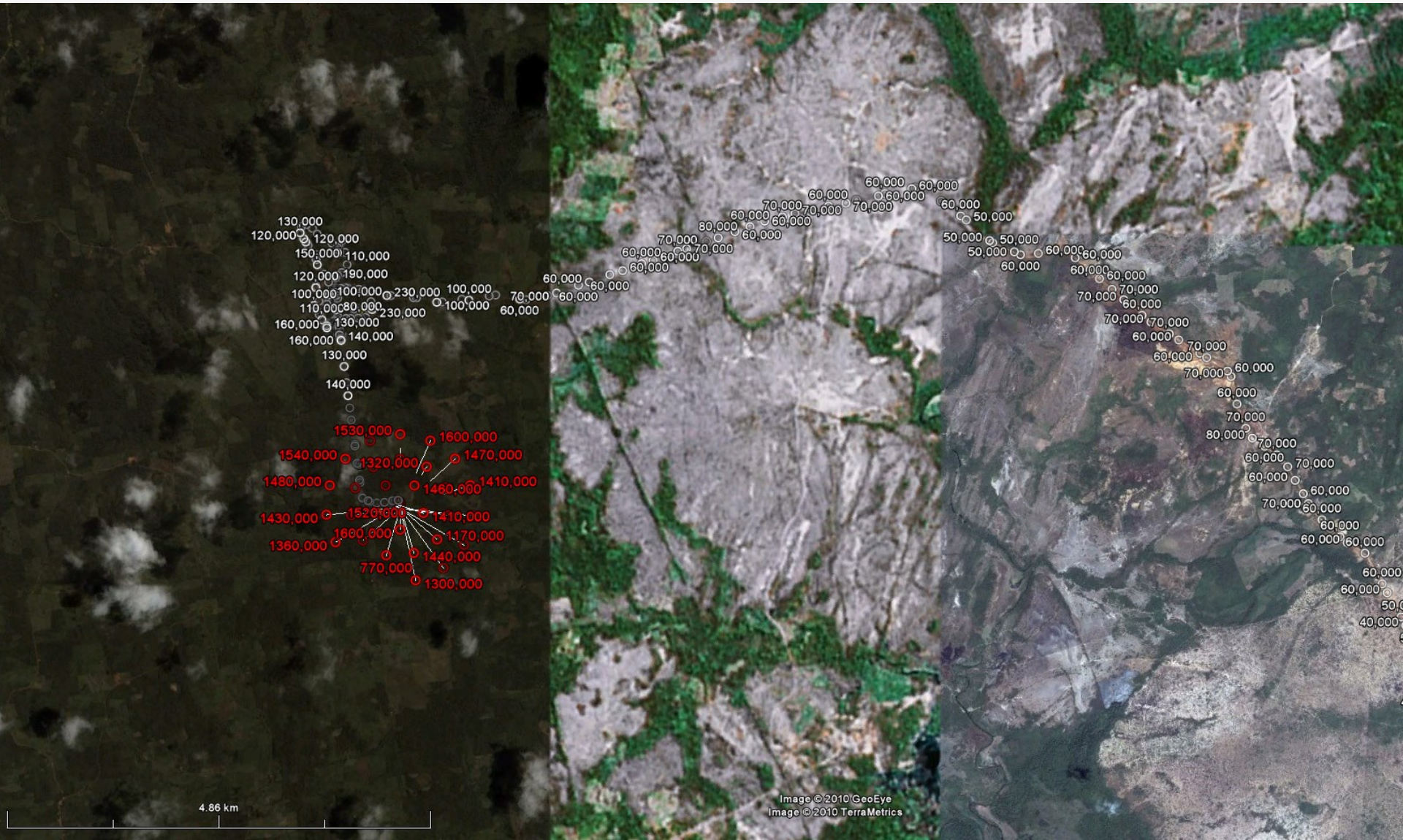
Resende -Nuclear Fuel Facility

Brazilian Base of nuclear-powered Submarine

Angra I and Angra II Nuclear Power Plant (Angra III in a near future) .

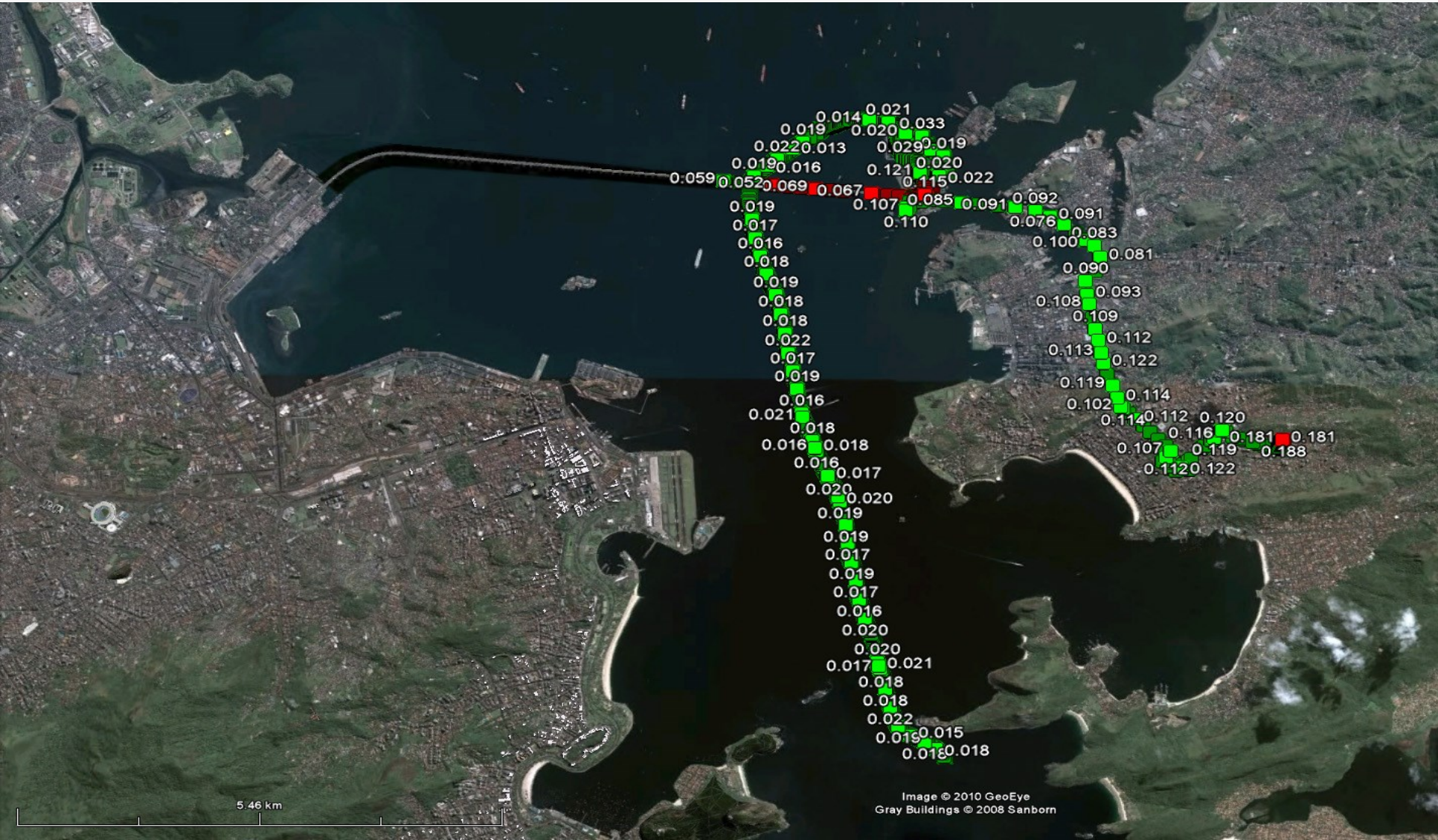
RESULTS I

Figure 11: Anomalies at Monte Alegre City, State of Pará, **H*(10) as high as 1.6 μSv/h .**



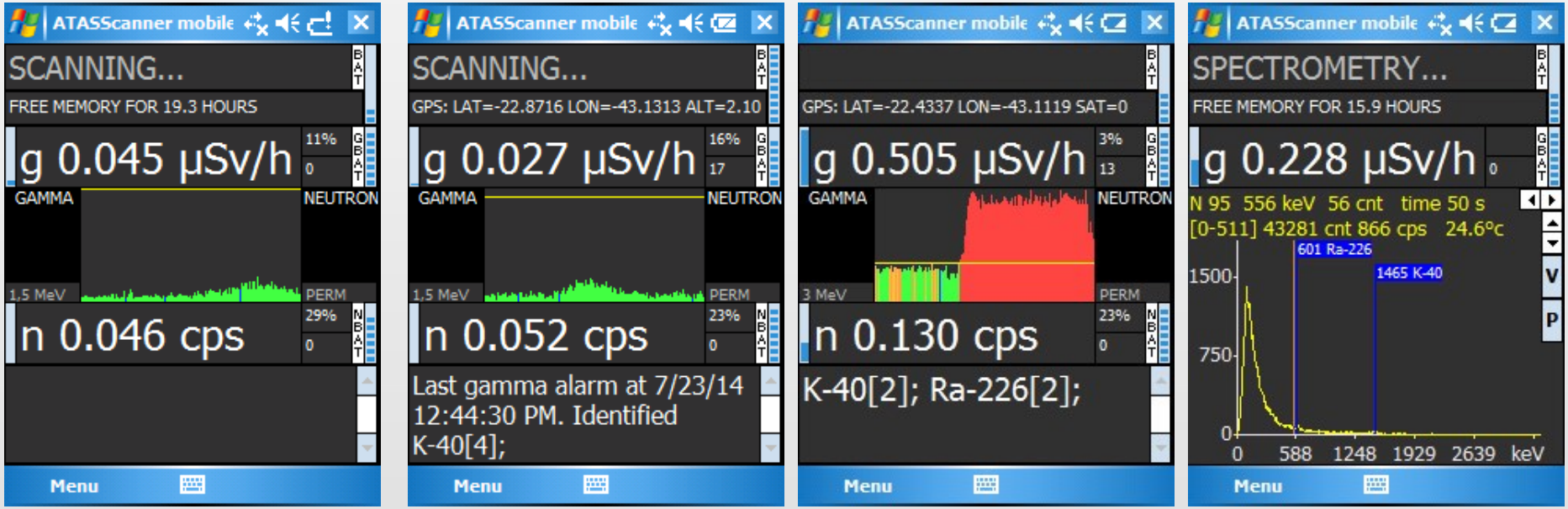
RESULTS II

Figure 12: Measurements at Guanabara Bay Rio de Janeiro and Niterói City



RESULTS III

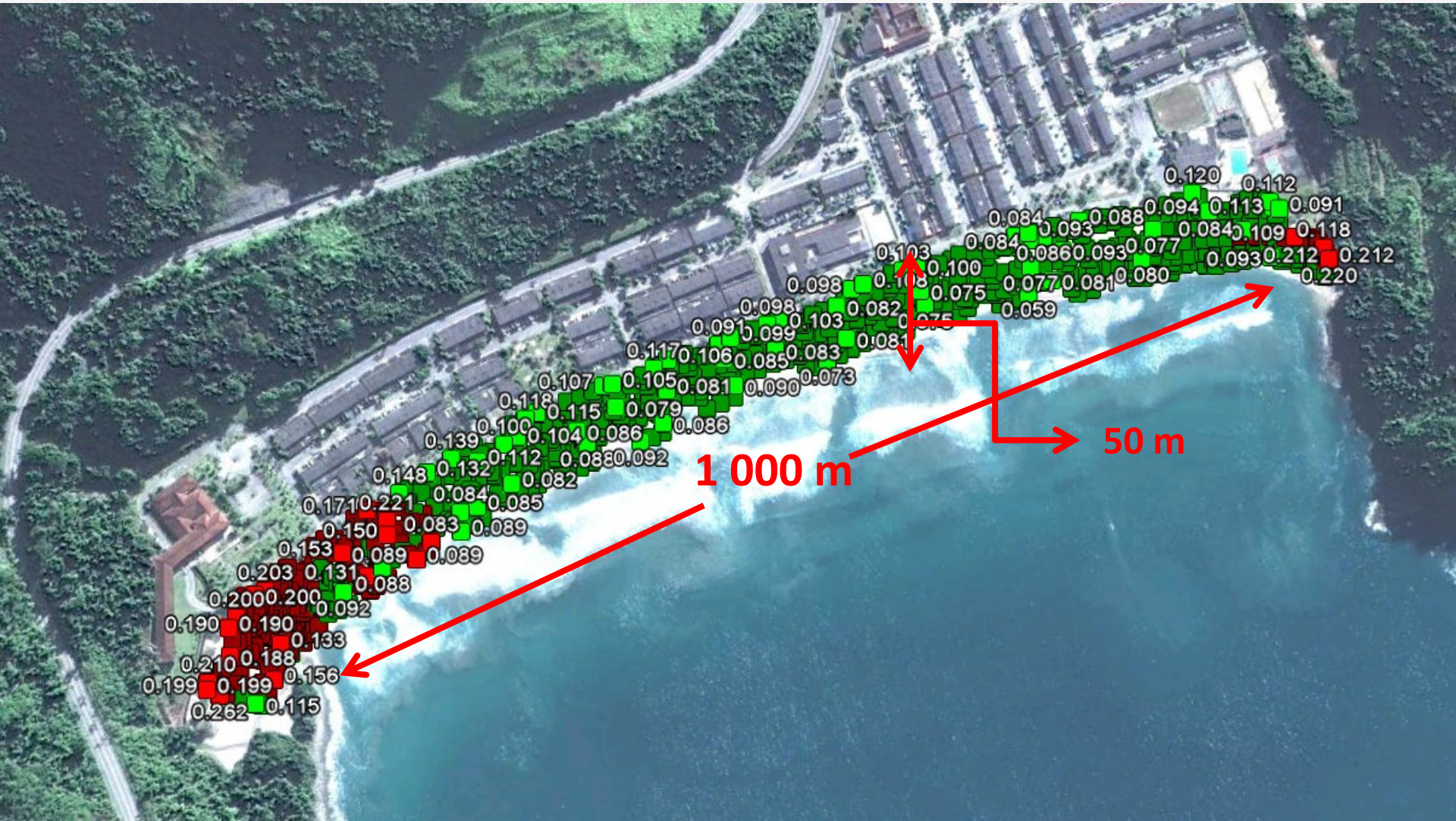
Figure 13: Measurements at Guanabara Bay Rio de Janeiro and Niterói City, effect of concrete structure on radiation field, with 1.5 MeV energy limit (a, b) and spectra of measurements at 3.0 MeV (c , d)



a b c d

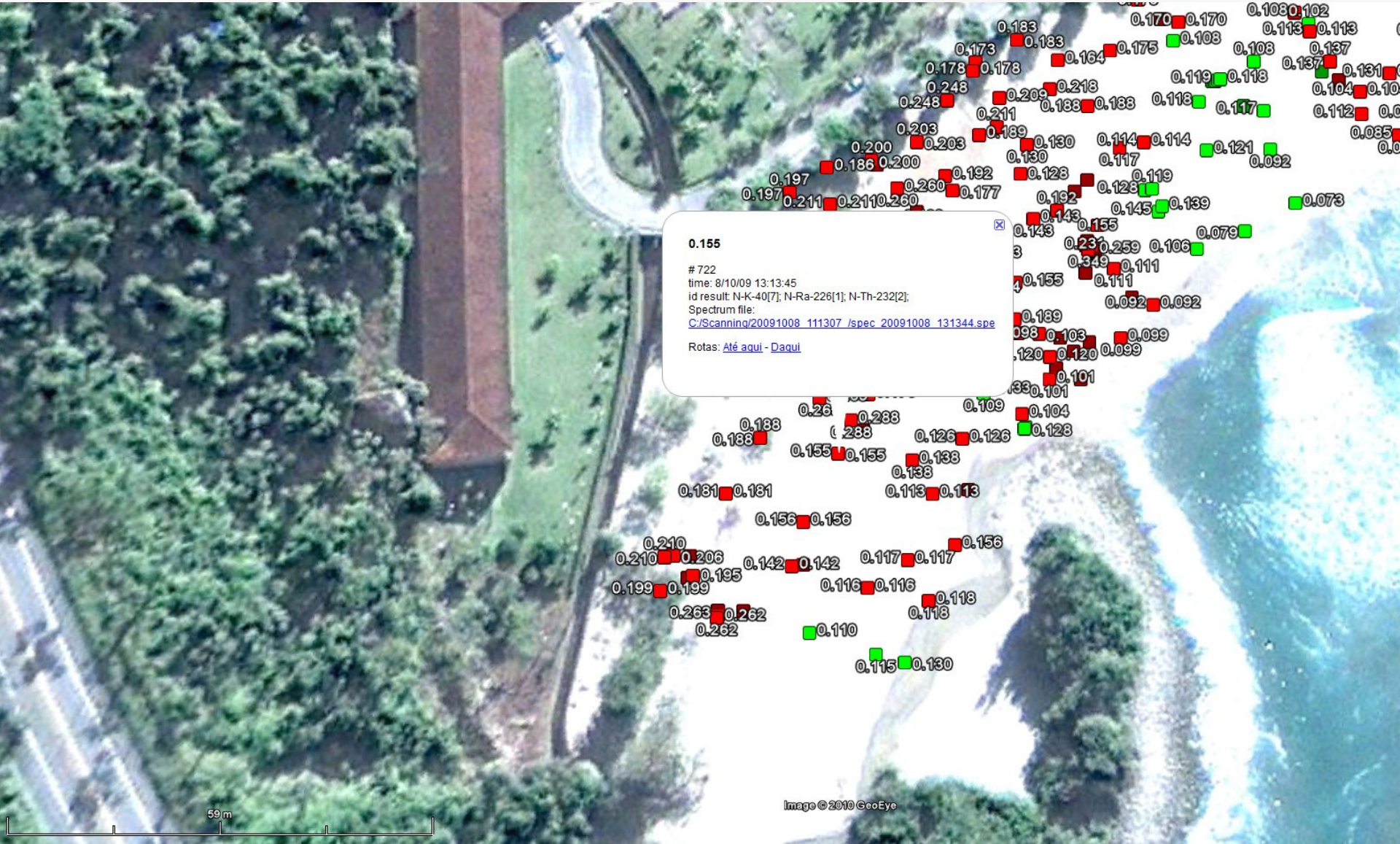
RESULTS IV

Figure 14: Measurements at Praia Brava Beach , near Angra NPP



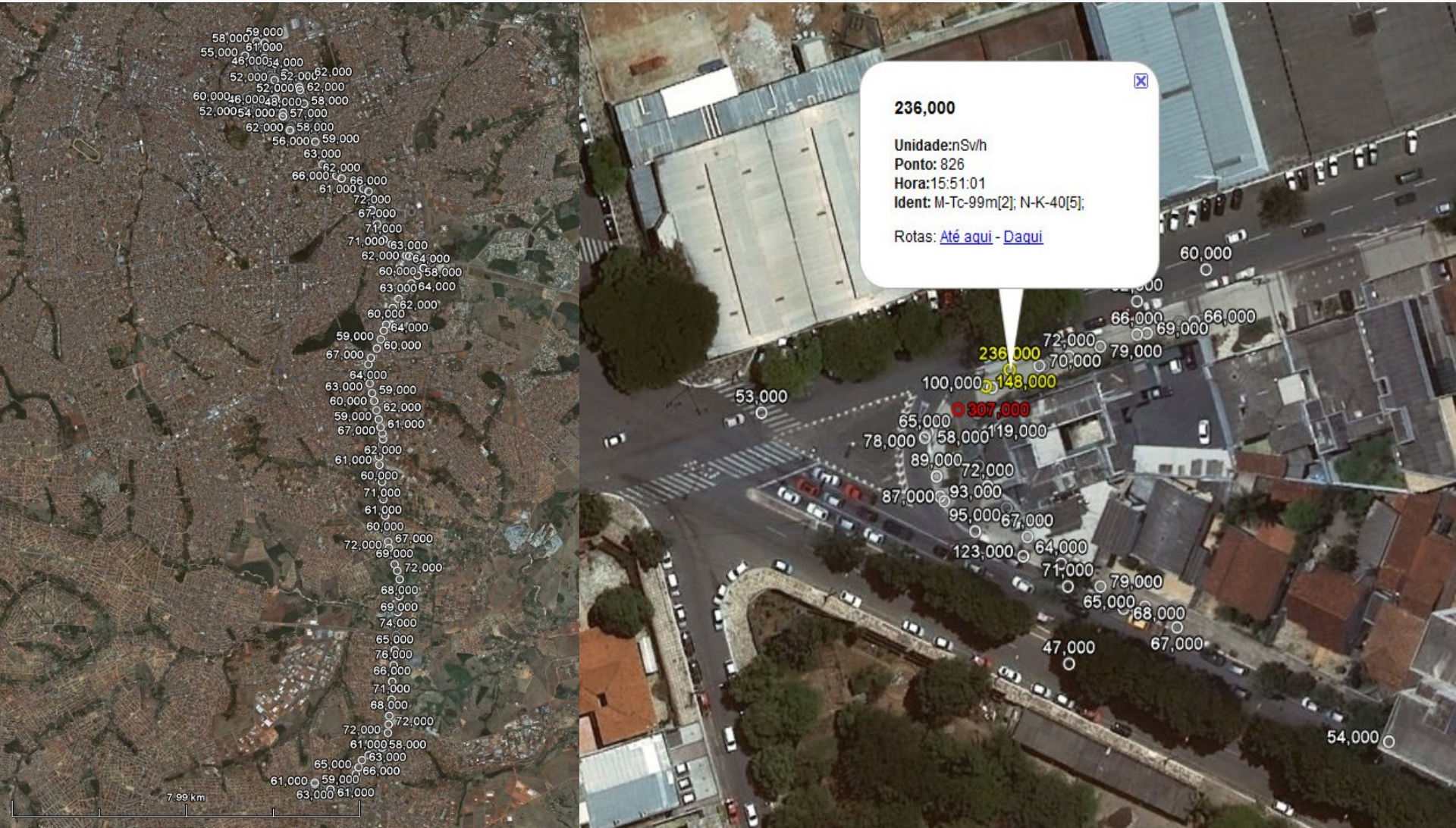
RESULTS V

Figure 15: Details of ^{226}Ra and ^{232}Th found in the sands



RESULTS VI

Figure 16 : Survey in Goiânia (^{137}Cs accident in 1987) and details of a person with ^{99m}Tc



RESULTS VII

Figure 17: Survey on Itaguai Bay and future installations of Brazilian Navy Base

RESULTS VIII

Figure 18:
Detail of Martins Island: Near the beach decorative stones used in fences and houses increase the dose rate from ~30 – 50 to 250-360 nSv/h

DETAIL OF “ANNOMALY” POINT AT MARTINS ISLAND

Figure 19: Martins Island full view and zoom

RESULTS IX

Table 2: Average values of H*(10) in nSv/h, and minimum and maximum values.

Town	Average	Min	Max	Reference
Fortaleza	80	19	190	[1]
Sauípe	47	19	104	[1]
Salvador	43	39	52	[2]
Vitória	96	54	257	[1]
Niterói	105	75	151	[2]
Rio	96	75	126	[2]
Angra	147	121	172	[1]
Sorocaba	75	30	100	[4]
Iperó	43	31	63	[4]
Martin Is.	40	19	364	[3]
Amazon R.	10	10	20	[3]

CONCLUSIONS

- **It is not possible use a general media for H*(10) without consider the different pavements and use of the land.**
- The detectors should be calibrated and checked against sources as similar as possible to the "actual survey areas".
- At low radiation levels the cosmic component should be considerate.
- **Even in urban area we found values very different mainly because the type and use of soil**. A layer of asphalt can shield a former stone pavement decreasing the background or the same asphalt can increase the background when it was placed over land or sand.
- The union of gamma in situ measures with the results of spectrometric analysis of sampled materials will allow a more precise evaluation and adjustment of models needed for environmental monitoring of specific areas (anomalies, facilities and etc…)
- The sampling alone could not provide representative values of dose rate. We have to consider the in situ measurements also.

CONCLUSIONS II

- Average dose rates [H*(10)] for natural areas – with no radioactive anomalies fall in the range of 80 ± 23 $nSvh^{-1}$ (Fortaleza-CE) to 147 ± 16 $nSvh^{-1}$ (Angra dos Reis-RJ) but during over water measurements were found values ranging from 10 – 25 $nSvh^{-1}$ (Amazon River to Guanabara Bay).

NORM VIII - EIGHT INTERNATIONAL SYMPOSIUM ON NATURALLY OCCURRING RADIOACTIVE MATERIAL

Rio de Janeiro, Brazil, October 18-21 , 2016

Scientific Papers - AUTHORS

Concise papers (papers should not exceed four A4 pages) on issues falling within the scope of the symposium (see Topics listed in the Announcement) may be submitted as contributions to the symposium. All papers — other than invited overview papers — must present original work and must not have been published elsewhere.

IMPORTANT DATES

Call for contributed paper opens:	**30 October 2015**
Papers submission deadline:	**18 May 2016**
Notification to authors:	**18 July 2016**
Final paper submission:	**18 August 2016**

MUITO OBRIGADO!
THANK YOU VERY MUCH!

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